MOORE - ON ICE-HOUSES AND REFRIGERATORS - BALTIMORE 1803

AN ESSAY

ON THE MOST ELIGIBLE

CONSTRUCTION OF ICE-HOUSES.

ALSO,

A DESCRIPTION

OF THE

NEWLY INVENTED MACHINE

CALLED THE

REFRIGERATOR.

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BALTIMORE,
PRINTED BY BONSAL & NILES, NO. 173,
MARKET-STREET.

1803.

16694.

PREFACE.

IN the consideration of the following subjects, I have been led into some investigations rather more abstruse than I was at first aware of, and probably to the correct eye of science, some aukwardness in the management of them may be discoverable; this is what might be expected when the farmer affects the philosopher. Although it is certainly necessary that the intelligent farmer should understand the tendency of all his operations, yet I can cordially unite in the sentiment, that in general he had better be attending to the business of his farm, than to nice philosophical disquisitions; for my own part, as the height of my ambition is to become a good practical farmer, I have mostly believed it proper for me to leave them to the discussion of the professors of science, and to avoid giving up much of my time or attention thereto. But having in very early life acquired a small stock of philosophical knowledge, and at times since paid a little attention to new discoveries, I am enabled in my own way, simply to investigate subjects which sometimes present in which the comfort of mankind seems to be involved; and when any useful hints appear to be thereby developed they certainly ought not to be withheld merely because they cannot appear in the most elegant dress.

AN ESSAY, &c.

AGREEABLY to an intimation given the public some time since I shall now endeavour to give some practical directions for the construction of *Refrigerators*, and (as being connected therewith) also attempt an investigation of the theory and practice of the art of preserving ice through the summer.

I STATED in a publication which circulated through several newspapers in the United States, that I had no pretensions to the discovery of new principles in the construction of the Refrigerator. The particular mode of applying some before known and understood, is all I claim as my invention; the utility of which has been fully proved during the last summer.

WHAT I have to observe on the keeping of ice is merely an attempt to carry improvements already begun a step further than I have yet heard of. I have apprehended, the reason why the art has not progressed faster, is because no one has yet fully investigated the principles upon which it depends; or, if this has been done by individuals, they have not favoured the public with a knowledge thereof. This is my present object, and for reasons which will hereafter appear, I prefer going through it, before I enter on the subject of Refrigerators.

In treating this subject, it will be necessary to lay down certain positions relative to heat; some of which have not been well understood until very lately. All that I shall

offer, have however been fully established by actual experiment. And in order to be as consise as possible, I shall avoid refering to the different writers who have published those valuable discoveries to the world. Philosophical readers will know where to look for them, and those of a different class, it is presumed, will not wish to be troubled with such references or quotations.

Water is converted into ice at the temperature of 32° of Farenheit's Thermometer; and as long as any water remains in contact with the ice, the temperature of the ice will remain nearly stationary, but when the water is all frozen, the ice will gradually give out its heat to the incumbent atmosphere, until it acquires the same temperature. Ice exposed to an atmosphere at any temperature above 32°, or, if placed in contact with any substance above that degree of temperature, will, in either case be melted. The temperature of the earth a few feet below the surface in this climate, is generally found to be between 50 and 55°. If therefore a pit be sunk in the earth and filled with the coldest ice, (which may sometimes be obtained as low as 10° by removing it from the water and exposing it to a very cold atmosphere,) the consequence will be, that the earth will give out heat to the ice, until the temperature of the mass is raised to 32°; the process of melting will then commence, and continue to go on, as long as ice remains. But this process will not be as rapid as those who are unacquainted with the subject might imagine: It would seem, that as melting ice is always found to be at the temperature of 32°, that after the mass becomes raised to that degree, the smallest addition of heat, would immemediately convert the whole into water; but this is not found to be the case; to prevent it, one of the many wonderful properties of matter interposes; and which only enables us to preserve ice at all. This is the difference be-

tween water and ice in their *capacities for heat.* As I would wish to be clearly understood by every class of readers, and as I may probably have occasion to repeat this term, it will perhaps be proper, to give a definition of it. The capacity for heat which a body is said to possess; is, its propensity or power of imbibing and retaining a greater or lesser quantity of that fluid, and at the same time appear to be of the same temperature as a given standard, which may contain a much greater or smaller quantity. Thus in the subject under consideration, the capacity of water for heat, is greater than ice; it being found by experiment, that ice at the temperature of 32°, requires the addition of no less than 146° of the same scale, or thereabouts, to reduce it to water. To elucidate the subject still further, let a pound of water at the freezing point (to wit) 32°, and a pound of ice at the same temperature, be put in situations where they will both receive an equal quantity of heat; when the ice is all melted, it will be found that the water has acquired 146° of heat, and of course will be at 178°. Or take a pound of water at 178°, and a pound of ice at 32°, put them together and cover them in a fit vessel, the ice will be melted and the mixture will be 32° or very nearly.

It appears then, that ice at 10°, deposited in a pit as before mentioned, and being in this solid state capable of conducting heat, must receive a sufficient quantity to raise the whole mass 22°, before any will be melted; when the melting process commences, it will cease to be propagated to the internal parts, because all that is received at the surface, will go to supply the increased capacity of the water; and this will be produced in direct proportion to the heat received. The whole quantity requisite to melt all the ice, being just as much as would raise the temperature of the same weight of water 178°. The greater the quantity of ice,

the longer it will be in melting, because, their will be less surface in proportion to its weight, and experience has proved, that the quantity may be so great, as not to be all melted during a whole summer, in this situation.

It seems then, our whole business is to guard against the introduction of heat; and in order to take effectual measures for this purpose, it is necessary to be acquainted with, and attend to, the following principles. That heat is transmitted with more difficulty through some substances than others; that it passes through fluid mediums, by transportation, or the interchange of particles; and not from one particle to another, as in solid bodies. The capacity of air for retaining moisture is greatly increased by heat. The power of air to conduct heat is increased more than four fold by moisture. An unequal distribution of heat in fluids, will always produce currents or interchange of particles; in general those of the highest temperature will rise to the surface; there is however an exception to this rule in water; between the temperatures of 40° and 32°, that fluid is more expanded than at temperatures a little higher, and consequently those particles which receive a small additional heat, will descend. To this extraordinary property in water, is to be ascribed some of the most wonderful phenomena in nature; but does not affect the subject under consideration. Substances which transmit heat freely, such as the metals, are called conductors of heat; and those through which it passes with difficulty, such as, wool, fur, &c. are called nonconductors; and they are called good or bad conductors, or nonconductors, agreeably to their degree of conducting power.

The forgoing principles and laws of heat being understood, will enable us to detect the defects of ice houses in common use. In the most improved kinds I have seen,

the ice is enclosed in a case of plank, or logs, within the pit; an interstice being left, between the sides of the case and the pit; which is commonly filled with straw; the ice reposing on a loose floor of plank or logs, raised a little above the bottom of the pit. Let us now suppose the case just filled with ice, defended from winds aud sunshine, but no straw, or other nonconductor, either at the sides, or on the top; how will it be affected as the weather becomes warm? The particles of air reposing on the upper surface of the ice, will soon acquire the same temperature, and those above them which are warmer, not being capable of parting with any portion of their heat to them, the first will quietly remain in their places, in consequence of their greater specific gravity; and of course, very little of the ice will be melted at its upper surface. At the sides it will be differently affected: heat will be communicated from the earth to the particles of air in contact with the sides of the pit, and being thereby rendered specifically lighter, they will of course begin to move slowly upwards; their places below will be filled by those which have not yet become rarefied; and these settling down from the sides of the ice, will leave a vacancy towards the top. This will occasion the ascending particles to incline towards that vacancy, and finally to pass over; then parting, with their acquired heat to the ice, become again condensed, and in their turn descend. Thus a regular current will be established, up the sides of the pit, and down the sides of the ice; and by this transportation of heat, a considerable portion of the ice will be melted. But as heat is much easier propagated upwards than in any other direction, it follows, that a far greater quantity will be communicated to the under surface of the ice, than to the sides, even if the stratum of air between it and the bottom of the pit were to remain dry. But it has been premised, that heat encreases the capacity of air for moisure, and that moisture encreases its power of transporting heat

at least four fold. The dripping from the ice will soon afford moisture in abundance; the particles of air at the bottom will always receive heat from the earth, and becoming at the same instante saturated with moisture, they will ascend with rapidity from every part of the bottom, communicate their contents to the ice, and descend with the same velocity to obtain a fresh supply. So that the quantity of ice melted at the sides, will bear but a small proportion to the loss it will sustain at its under surface.

From what has been said, it will easily be perceived, that this mode of insulating ice with atmospheric air, is much to be prefered to filling the pit entirely with ice as first mentioned; because, it cannot be supposed that air, which is only capable of cunducting heat by means of the internal motion of its particles, even in the state most favorable for the purpose, can convey it from a warm, to a colder body, with the same facility that it would be conveyed were the two bodies in actual contact. But experience has proved, that the conducting power of air may be much lessened by filling it with such nonconducting substances as will embarrass the particles in their passage: this is the use of straw between the ice and the sides of the pit, as now commonly used; but notwithstanding the waste of ice is abundantly greater at the bottom, than at the sides, as we have just seen, yet I have not known similar precautions taken to prevent it. Indeed it is questionable whether the same material, used in the same way, would answer any valuable purpose, because the water that would be continually dripping on it, would, I believe greatly lessen its power of resisting the passage of heat. There are however other nonconducting substances, which I think may be arranged in such a manner as greatly to prevent the loss sustained at the bottom of the ice; therefore, the next consideration is

What is the most eligible construction for an Ice-house?

I WILL not undertake to say I am fully prepared to answer this question; although I am persuaded that the foregoing statement of the principles on which it depends is correct, and the observations founded thereon are corroborated by experiment as far as I have had opportunity of attending thereto. Yet I have no doubt but further experience will suggest to intelligent observers, improvements which do not now occur. I will however offer a plan the most simple and cheap that I have yet thought of consistent with the principles laid down.

THE most favourable situation is a north hill side near the top. On such a site open a pit twelve feet square at top, ten at bottom and eight or nine feet deep: Logs may be laid round the top at the begining, and the earth dug out raised behind them so as to make a part of the depth of the pit. A drain should be made at one corner; the spout to carry off the water should descend from the pit except a short piece at the outward extremity which ought to rise thus,  the depressed part will aways stand full of water and prevent communication with the external air. Dig holes in the bottom of the pit and set therein four perpendicular corner posts and an intermediate one on each side; let the insides of these posts form a square of eight feet in the middle of the pit. Then in order to avoid dampness from below, cover the bottom three or four inches deep with dry sand, if it can be conveniently got. The next thing to be done, I consider as the most meterial and also expensive part of the business; which is fixing a proper floor for the ice to rest on. In order to do this, let three or four sleepers supported at the ends be placed across the square included by the posts; their upper edges about a foot from the bottom, but

so that the plank laid thereon may have a descent of a few inches towards one of the sides next the drain. The plank should be two inches thick and about half seasoned; jointed, grooved and tongued or lathedand grooves cut near the joints, in the upper side so as to prevent any water from going through. The floor must extend a little without the inner sides of the posts; so that the water dripping from the sides may fall on the floor. Then fix a plank, or spout at the lower end of the floor in such a manner as to convey the water into the drain. The floor being compleated, begin at the bottom and plank up on the insides of the posts with $\frac{3}{4}$ or $\frac{5}{8}$ plank, lapping the lower edge of each a little on the one below so that the water may be kept on the inside: this done to the top of the posts (which should be even with the top of the pit) and the inside will be compleated; except that it will be proper to cover the floor with loose plank previous to putting in the ice. The roof may be composed of any materials, and in any form that will defend the contents of the pit from wet, from the direct rays of the sun, and also admit a free circulation of air: I do not think any could answer the purpose better that one made of thatch, supported by posts a few feet from the ground.

The mode of filling the house remains now to be considered; and on this much depends.

Early in the winter fill the interstice between the ice chamber and the bank with clean dry straw closely pressed; this being done early, will prevent the earth from freezing; which would be injurious to the sides of the pit. The ice should be collected in the coldest weather; let it be exposed at least one night to the cold atmosphere after it is removed from the water; which will reduce its temperature many degrees, if the weather is severe. When

put into the house, it should be beat small, and I think it would be useful frequently to sprinkle it with a watering pot whilst putting in; the mass would by that means be rendered more compact. When the chamber is filled, cover the whole with a good thickness of straw; but I should suppose it would be best to cover the ice first with plank, supported by the sides of the chamber, only leaving a door to descend through.

Such a house as has been described will contain about ten ton, and I am persuaded will be found sufficient to afford an ample supply for almost any private family.

This is nearly the kind I had in view when I estimated the expence would not exceed twenty dollars: and if we calculate on a great part of the business being done by the family; which in the country in general, it very well may: the actual out lay, in many places need not be five dollars. Those who are less sparing of expense, if they choose, may wall, or what is better, plank up the sides of the pit; and finish the roof in a stile of elegance.

In level situations, where a drain cannot be conveniently dug out from the bottom of the pit; I should suppose it would answer very well to enclose the ice by a mound raised entirely above the surface of the earth, through which the water may be discharged; in other respects to be similar to the foregoing description. This perhaps would not be quite so cool a repository as if under the surface of the earth; unless the mound was very thick; but I am persuaded that the loss of a few degrees in temperature bears very little proportion to the advantage resulting from dryness.

If it were certain the floor would be perfectly tight, the passage of heat to the ice would be rendered still more difficult by confining a quantity of dry ashes, saw-dust, straw, or some other nonconductor between the floor and the bottom of the pit.

OF REFRIGERATORS.

THE preservation of ice and the economical *use* of it, depend on the application of principles so nearly similar, that a treatise on ice-houses ought to lead to an understanding of the construction and use of *Refrigerators* (this being the most appropriate term I have thought of for the machines intended to be here described) and the common method of defending our bodies from the inclemencies of the atmosphere by cloathing, if attended to, will instruct us in both.

HEAT is supposed to be excited or generated in animals by the continued action and re-action of the vessels; if then it is continually generating it is absolutely necessary that a certain portion should be conveyed away, or the system would soon be destroyed: on the other hand if conveyed or extracted faster than generated, the system would also be destroyed by the contrary extreme (to wit) the fixidity of all its fluid parts. Nature alone has defended brutes from the effects of these two extremes, and nature and art combined have effected the same thing for man. The surrounding atmosphere serves as a conductor to carry off the surplus heat; but when the atmosphere becomes so cold as to absorb it faster than it is generated in the body, in order to prevent inconvenience from the change, art has introduced the use of cloathing, which renders its escape from the body more difficult.

Now if we can by any means in summer, reduce the temperature of a portion of atmosphere a little below 50° of farenheit's scale, and can enclose the same with *such a*

cloathing as will prevent any accession of heat from without, we have a refrigerator in which fresh meat when reduced to the same temperature will not putrify: and if we can still reduce the temperature to a little below 32° and preserve it so, we shall then have one in which water and some other liquids will freeze. To effect these purposes at a small expense has been the object of my enquiry; and may say I have succeeded quite equal to my expectations.

I KNEW that if a tight vessel composed of some good conducting substance was surrounded on all sides with ice, that the heat of its contents whatever they were, would pass rapidly through its sides to the ice, until either the ice was all melted, or the vessel and its contents were reduced to the same temperature: but then, while this process was going on, the ice, if exposed in warm weather would also receive large quantities of heat from the atmosphere; so that to preserve a vessel and its change of contents in this situation, would require such a quantity of ice as to render it both troublesome and expensive; it therefore appeared necessary to contrive such a covering for the ice, as would defend it as much as possible from any heat, except what was received from the thing intended to be cooled. In order to do this, and at the same time to have a vessel of a convenient shape, I had a cedar vessel made in the form of an oval tub, nearly as wide at bottom as top; in this was fitted as large a straight sided tin vessel as it would contain, open at the top: This of course left interstices between the sides of the tin vessel and the wood, and also at the ends; these interstices were covered by an edging of tin, which was soldered to the upper edge of the tin vessel, and extended on to the upper edge of the wooden vessel, to which it was nailed; (but this edging which connected the two vessels at top, would have been better of wood.)

Through this last was cut a hole about an inch and a half square on each side, for the purpose of putting in ice. Over the whole was fitted a wooden lid fastened by a hinge on one side. A coat or case was then made for it which consisted of coarse cloth lined with rabbit skins, the fur side next the cloth and the pelt next to the wood. The coat was in two parts for the convenience of raising the lid; the part attached to the lid had an edging which hung down and covered the joint when shut.

This being only an experiment, was made on a small scale; the tin vessel being only 14 inches long, 6 wide and 12 deep: It was used for carrying butter to market, and contained 22lb. Before the butter was put in, small lumps of ice were introduced through the holes into the open spaces left between the sides of the two vessels; the butter, weighed off in pounds, by a peculiar and very expeditious mode of printing, was formed into the shape of bricks, with a device and initial letters in cypher on one side; these being wrapt separately in linen cloths as usual, were put in edgewise: The first tier always became so hard in a few minutes, that the remainder might be built upon it without injuring the shape. When all was in, pieces of cloth were laid over the holes made for putting in the ice, and the lid shut down and fastened. In this condition it was put into a carriage and carried twenty miles to market; but because there was always butter put up in the usual way, and other things to take at the same time, it was carried in the night; had it not have been for this circumstance, there would have been no occasion for going in the night. The butter in the hottest weather was always delivered so hard, that it was difficult to make any impression on it with the finger. Sometimes, after having been exposed in market and frequently opened, when all was sold out, it has been again filled with other butter so soft as

scarcely to admit handling, which in a little time has been taken out nearly as hard as the other; and after this, ice has remained in the machine most of the day. When the ice is melted, the water is drawn off at the bottom, or poured out at one of the openings in the top.

The quantity of ice made use of in these experiments, was not fully ascertained; but was proved to be at least twice as much as would have answered the purpose, had the spaces left for it have been only half as large. The whole cost of this machine was about four Dollars: The butter always commanded from 4d. to $5\frac{1}{2}$d. per lb. higher price than any other butter in market; so that four times using it paid the cost.

In this machine, the heat passes freely from the butter through the tin (which is a good conductor) to the ice, and the ice being surrounded by several good nonconductors, it can receive but little in any other way. The nonconductors are first, the cloth; secondly, the fur on the rabbit skins; thirdly, the thin sheet of air confined between the pelts and the wood; and fourthly the wood it self. Yet through all these, a small quantity of heat will find its way; which we are to expect will be the case in any arrangement that can be made; but with proper care the quantity will be so small that its effects may be easily overcome.

The following are some of the useful purposes to which the machine may be applied, besides the one already mentioned. Every housekeeper may have one in his cellar, in which, by the daily use of a few pounds of ice, fresh provisions may be preserved, butter hardened, milk, or any other liquid preserved at any desired temperature; small handsome ones may be constructed for table use, in

which liquids, or any kind of provisions may be rendered agreeable, as far as it is possible for cooling to have that effect. Butchers, or dealers in fresh provisions may in one of these machines, preserve their unsold meat without salting, with as much certainty as in cold weather; and I have no doubt, but by the use of them, fresh fish may be brought from any part of the Chesapeake bay, in the hottest weather and delivered at Baltimore market in as good condition as in the winter season. But for some of these purposes, and perhaps for all, it will be found eligible to alter the arrangement of materials, and also to make use of some other kinds; particularly for those which are large and are not intended to be often removed.

After constructing and using the Refrigerator which has been described, as its usefulness depended entirely on a supply of ice; I was naturally led to reflect on the most economical means of preserving it, and hence the foregoing investigation of the subject. In the course of that investigation an improvement in the Refrigerator occurred. I clearly discovered, that agreeably to the laws of heat, any refrigerating body placed in the upper part of a chamber defended from external heat, would certainly receive heat from the atmosphere of the chamber, until a common temperature was produced. I therefore concluded, that if a small tin vessel was attached to the under side of the lid, of the Refrigerator, to contain the ice only, and the lid made to slide instead of raising up, that the large tin vessel might be spared; which would certainly be a great improvement, especially as in that case there would be no absolute necessity for the wooden vessel to be water tight, and some difficulty attends keeping any other than a hooped vessel in that condition. In order to prove by experiment as far as I had convenience for doing it I removed the tin vessel from the refrigerator and placed a vessel containing water, and an-

other milk on the bottom of the wooden vessel, one at each end; I then fixed a pewter bason containing ice and salt, as near the top as I could to admit the lid to shut over it. I found both water and milk began to freeze in about an hour; and by letting them remain some time longer they were both frozen to the bottom; the temperature of the room about 55°. Having never before seen, or heard of any liquid being frozen by means of ice and salt in a temperature above the freezing point, in any other way than by placing the vessel containing the liquid intended to be frozen in contact with the mixture; this experiment as far as it went was encouraging. Some days afterwards the temperature of the room the same, I fixed the bason containing ice only, as before, and made use of a thermometer to try the effect. I was now disappointed by finding that I could not by this means reduce the atmosphere within the vessel as low as the ice by 6 or 8°. But on a little reflection the cause was very plain. The nonconductors enclosing that portion of atmosphere, were not so perfect but they admitted some heat to pass through, and this continually mixing therewith, before it could be taken up by the ice would of course always occasion a difference in temperature. This plan will not therefore answer the purpose as well as the other, either when a great degree of coldness is required, or when it is necessary to produce immediate effect. But for those on a large scale, such as would be proper to stand in cellars, or the holds of vessels, I think this last mentioned kind is to be prefered.

The following I think would be an eligible mode of construction. Suppose it is required to have one whose content shall be equal to six cubic feet clear of the ice vessel: let a box of wood be made three feet long two feet wide and sixteen inches deep in the clear: let another box be made of such dimensions that the first may stand within it;

leaving an insterstice between, on all sides, and also between their bottoms of about an inch. The sides and one end of the outside box should also stand an inch or more above the other. Then put as much dry sifted ashes, or, rather charcoal dust if it can be had, into the large box as will cover the bottom an inch deep; set the small box within the large one, leaving the space equal on all sides. Then prepare a lid, which may rest on the top of the inside box, after thin strips are nailed on the upper edges thereof, in order to cover the spaces left between the boxes; the edges of the lid confined by a ledge nailed to the outside box, or by a groove, and made to slide endwise: cut a hole of a convenient size near the middle of the lid for the purpose of putting in the ice, and connect a door to it by a hinge. The ice vessel must then be fastened to the lid: this should be made of tin or sheet iron, about two feet long, eighteen inches wide, and four inches deep, having a convenient opening at one corner to draw off the water, which may be stopped with a cork; the side and end plates must be five inches wide, one inch of which must have a square turn outwards to admit of its being nailed up to the lid, which will form the top of the vessel. This being done it will be necessary to cut away one end of both boxes so as to admit the lid with the ice vessel nailed to its under side to draw out. Then fill the space between the boxes at the sides and ends, with the same material used between their bottoms; nail on the strips to confine it in, and the wood-work will be finished. The whole may then be covered with coarse blanketing, dufile, or the cloth called lionskin; so cut as to admit of the lid being drawn out, and to cover all the joints when shut: at the end cut down, to give room for the ice vessel, it will be necessary to have a flap of several thicknesses of cloth, attached either to the end of the lid or box in such a manner as effectually to close the opening when the lid is pushed in.

An easier method of fixing the lid (and perhaps in most cases ought to be adopted) would be, to let the top of both boxes be of equal height and fasten the lid thereon, having an opening in the middle a little larger than the ice vessel, through which it may hang down, suspended by the edges of its wooden top to which it should be nailed as before directed, the joints to be all closed by the woollen covering. The only inconvenience that would attend this mode would be an increased difficulty in opening, on account of its having to be lifted off when full of ice, but this might in some measure be remedied by having suitable handles, and for those that are to be stationary a small pulley.

Such an ice vessel as has been described, will probably contain about 30lb. of ice in lumps; and is capable of cooling more than 120lb. of any kind of provision or liquids, put in at the average summer temperature, down to 6 or 8° below the coldest spring water. I have not consulted any meteorological tables on the subject; but believe I am safe in stating the mean temperature of this climate, from the middle of the fifth month, to the middle of the ninth month (which is about the time ice is useful) rather below 80°. It will then require any article at that temperature, to be cooled 30° to bring it to what was proposed. As it requires 146° or thereabouts of heat to convert ice to water; then, as many thirties as are contained in 146, so many pounds of the thing intended to be cooled, will each pound of ice cool to the degree required, admitting the ice to receive no other accession of heat. For the sake of round numbers, instead of 146, we will say 140, which divided by 30, quotes $4\frac{2}{3}$; 30 pounds of ice multiplied by $4\frac{2}{3}$ produces 140 pounds of the article to be cooled : if we strike off the fraction $\frac{2}{3}$, which will be just $\frac{1}{7}$ of the ice on account of that portion of external heat which will find its way in

while the articles are cooling, we shall then have 120lb. This is much more than almost any private family would have occasion to put in daily, for the use of the family only. There are however some deductions to make for the heat, which would be admitted by frequently opening, and also continually passing through the sides and bottom of the boxes.

But it is impossible to calculate with certainty on the subject without more accurate experiments than I have yet made. I am however of the opinion, that the average quantity of 20lb. of ice per day, will be sufficient in such a refrigerator as has been last described, to answer the purposes of a large family; even admitting, that with other things, the milk of two or three cows should be kept therein; when the weather is very warm, the necessary quantity will probably be greater, and proportionably less when cooler.

When it is required to produce a great degree of cold suddenly, it will be proper to beat the ice small and add about $\frac{1}{4}$ its weight of salt; the mixture will melt much sooner than ice alone; and because the freezing point of the brine their union will produce, is 38° below the freezing point of fresh water, and its capacity for heat being greatly increased on its passing to the fluid state, the mixture while melting, must necessarily be abundantly colder than ice; which constant experience verifies. After the brine has taken up so much heat that it is no colder than ice, it may be drawn off and used for cattle or any other necessary purpose. I should suppose this practice would be always proper for fishermen when their fish were first put in.

Before I leave this part of the subject it will not be amiss to notice a very erroneous practice which I am told some have fallen into. Knowing that a mixture of ice and

salt produces a great degree of cold, they have very injudiciously mixed salt with the ice when filling their ice houses. Strange as it may appear, yet it is certainly a fact, that by this practice about three times the quantity of ice will be melted, that would be by using the same weight of boiling water. This however is not all clear loss: it has just been observed, that four pounds of ice, or water, and one pound of salt, produce a brine whose freezing point is 38° below the freezing point of fresh water, or 6° below 0: this is the brine that will be produced by a particle of salt coming in contact with ice, at the instant of melting; being about the proportion of salt, which water at that temperature can dissolve: therefore, 1lb. of salt will liquify 4lb. of ice in an ice house at the temperature of 32°; 1lb. of boiling water will liquify about $1\frac{1}{4}$lb. But on passing to the liquid state, it takes from the adjoining ice as much heat as supplies its encreased capacity; which it is probable, is about 108°; 38° less than fresh water; this being the difference between their freezing points. Admitting the brine to flow off as fast as it is made, these 38° for each pound of brine or one hundred and fifty two for each pound of salt, is all the loss that will be sustained; because the ice that was cooled by the process, must be again supplied with the same quantity of heat, to raise it to its original temperature: the loss will therefore, be something more than one pound of ice to each pound of salt. If the brine was to continue some time before it passed off from the ice, the loss would be less; because its temperature woud be raised by heat taken from the ice: but as certainly as it leaves the ice any colder than the general temperature (32°,) so sure some loss is sustained; because the introduction of salt can do very little either towards increasing or diminishing the quantity of heat already in the ice house, or regulating the future supply. Its only agency,

goes to effect a speedy dissolution of the ice in contact with it, by borrowing as much heat from the ice in its vicinity, as will supply the encreased capacity of the new made liquid, which is about 108°; whereas without salt the same quantity of ice must have taken from the general supply, of heat (the same in both cases) as much as would raise its temperature 146° before it could be in a condition to flow away. Therefore, admitting it was possible for the brine to be retained until its temperature was raised to 32°, no advantage can be gained. Seeing then it cannot possibly be useful, and may do much harm, applying it in that way, must be worse than throwing it away.

After this digression, we will return to the subject of refrigerators. Twenty pounds of ice per day for four months is 2400lb, a small proportion of the quantity recommended to be stored in the ice house; but we are to remember, that after all precautions, we must expect a great deal more will be melted in the ice house than will be taken out for use. The mean temperature proposed for the inside of the refrigerator and its contents to be kept, (to wit) about 48°, and on which the calculation is grounded, is below the point at which the putrefactive process in flesh can commence: fresh meat may therefore be preserved a week, or longer if desired, in good condition, in the hotest weather: and all other kinds of provisions, fruits, or liquids will be found to be quite as cold as will be agreeable.

By attending to the foregoing instructions, it will not be difficult for an ingenious mechanic, to construct refrigerators upon either of the plans proposed, and to vary the form and size at pleasure, always attending

to the general rules; that the inside vessel must be of metal, and the outside composed of such metarials as we find by experience forms the warmest cloathing, or are least disposed to conduct heat.

A good method of determining whether any substance is a good, or bad conductor of heat, is, by heating or burning one end of a small piece of the same material, and holding the other end in the fingers: if it can be ignited, or burned close to the fingers, without much sensation of heat, it is a bad or slow conductor: if on the contrary, a sensation of heat is perceived when the ignition or burning is at some distance from the fingers; it is a good or quick conductor of heat.

Keeping these leading principles in view, refrigerators may be constructed of light materials, to contain, not only butter, but poultry, veal, lamb, and all sorts of small marketing, which are liable to be injured by carrying in hot weather: one of these may he filled, and its contents cooled; then draw off the water and add some more ice: in this condition, it may be put into a covered cart or covered carriage of any kind; may be on the road the whole of a hot summer's day, and be delivered at market in as good condition as in the winter season. This would entirely supercede the necessity of the unhealthy, and disagreeable practice of travelling to market in the night. If such refrigerators should happen to be made imperfectly, a blanket or two thrown over them and plenty of dry straw around them would be useful.

In the publication alluded to in the beginning of the essay on ice-houses, I expressed an unwillingness to render any invention of mine, in the least degree expensive to the poorer class of citizens; but I also expressed my inability to expend either money or time for the benefit of the

public without remuneration. I have therefore adopted the following plan, whereby every citizen will be at liberty to profit by the invention on his own terms with respect to price.

THE exclusive right is secured by patent. Any person will be at liberty to use gratis, for the purpose of carrying butter to ~~mark~~ market, one Refrigerator, of a size not exceeding nine inches cube, or 730 cubic inches in the clear, which if made of a suitable shape will contain 18lb.

FOR one of any other size, not exceeding a cubic foot, or, 1728 cubic inches; (which will contain 42 or 43lb) to be used for the same purpose, the price proposed for a permit, is 2 dolls. 50 cts.

FOR one of any larger size, to be used either for carrying provisions to market, or for family purposes; or both occasionally, 5 dolls.

FOR any number of small ones for table use for one family only, 5 dolls.

OR, for any number of any size or description for the particular use of one family only, 10 dolls.

BUT if any person in low circumstances, wishes to use any of the above mentioned sizes, for the purposes of marketing only; and who cannot well afford to pay for the privilege; he may on producing a certificate, signed by three reputable neighbours, certifying that such are his circumstances, obtain a permit gratis.

Or, if any more wealthy person, shall apply for a permit for any of the sizes; to be used for any purpose; and will declare, that *he believes the terms are hard and improper*, and is therefore not willing to pay any thing, he shall obtain a permit gratis.

But in order to prevent the abuse of the foregoing plan, (which I think most of my fellow citizens will acknowledge is a liberal one) there will be a regular record kept of each persons name, his place of abode and the terms upon which which he obtains a permit; and it will be an indispensible condition, that in every case, even in the first mentioned, a permit must be obtained. Those who act contrary to this condition will make themselves liable to the penalties of the law.

If on further trial the invention is approved, and applications become numerous from a distance; I propose appointing agents in several of the large towns in the United States; at present I have appointed none; but any letters covering the proposed fee, certificate, or declaration, as above mentioned, post paid, directed to, Thomas Moore, Brookeville, Maryland, will be duly attended to.

If it were necessary, the names of a large proportion of the citizens of George-town and Washington, might be offered, who would testify to the truth of the description of the refrigerator used by myself last summer; a certificate to that purpose from three of the principle inn-keepers of these places, and another well known character, appeared at the foot of the first publication on the subject; but after the explanation which has been given of its principles, I believe intelligent readers will hardly think it necessary.

FINIS.